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(54) Apparatus and sensor unit for monitoring changes in a physical quantity with time.

(57) Apparatus for monitoring changes in a physical quantity with time comprises a reader unit (1) and at least one sensor unit (2) containing electronic components (20, 21, 23, 24 and 25) arranged to measure the physical quantity at predetermined time intervals and to store measurement data with corresponding time data. Each sensor unit (2) also contains communication means (26) for transferring the measurement data and the time data from the sensor unit (2) to the reader unit (1), and the sensor unit (2) also contains an inductive coupling means (24) to receive energy from the reader unit (1) to power the communication means (26). Each sensor unit is encapsulated with a food grade plastic and is typically the size of a credit card, thereby providing a small and relatively inexpensive temperature monitoring device for use in the transport and storage of foodstuffs.

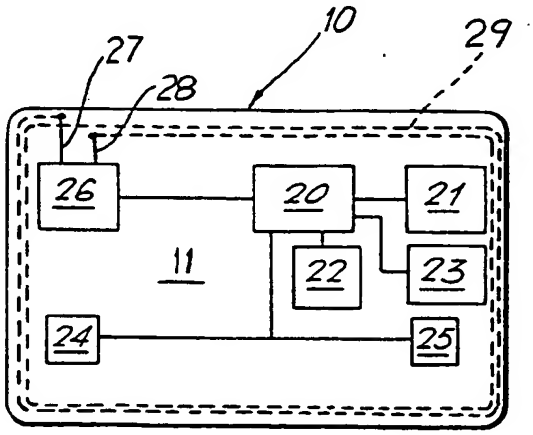

FIG.2.

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This invention relates to apparatus for monitoring changes in a physical quantity with time. The apparatus may be used, for example, to monitor the temperature of foodstuffs in storage and transit.

Food hygiene regulations impose increasingly strict requirements for the handling and storage of foodstuffs, and it is desirable to be able to establish reliably that, over a given period, the correct storage temperature has been maintained to suppress the growth of bacteria, for example. Various devices are available which can be placed in the food container, for example a vehicle, to accompany the food and to measure and record the temperature within the container at predetermined intervals, recording at the same time the date and time of the measurement. When the food reaches its destination, the temperature and time measurements recorded in the device are read into a computer by connecting the device to a reader unit.

In order to ensure sufficient battery power is available to operate data measuring and recording functions reliably over a long period, and to permit transfer of the data to the reader unit, known devices generally are relatively bulky and costly to manufacture. This limits their application, since they occupy space which would otherwise be occupied by foodstuffs, and the cost of including one or more of the devices with every load of foodstuffs can be prohibitive. As a result, therefore, most existing devices tend to be used for random testing, travelling with selected loads, rather than for monitoring every load and thus enabling responsibility for spoiled foods to be established, or at least to be avoided, by the user of the devices. There is therefore a need for a temperature monitoring system which includes small and relatively inexpensive temperature monitoring devices which can travel with every vehicle load, or even with every pallet load within the vehicle.

The specification of US Patent No. 4,972,099 discloses a portable sensor card in which an external physical phenomenon can be sensed and the sensed value subjected to signal and data processing and the results of processing stored, and in which the stored data can be read out to an external device. More particularly this publication teaches a sensor card comprising a single card substrate on which are mounted a sensor, an integrated circuit having a memory, and an output terminal. The sensor card is used to detect and record the temperature of the environment of food or living things during transportation and includes a sound-emitting element for generating a predetermined warning tone when the microprocessor detects a sensed temperature outside allowable limits. The sensor card incorporates its own power supply, in the form of a battery imbedded within the card substrate, and has an external connection terminal for connection to an external device such as a personal computer. This sensor card is relatively bulky due to the imbedded battery which needs to meet all its energy requirements. Furthermore, the external connection terminal and the projecting sound-emitting element both provide recesses in which foodstuffs, dirt and associated micro-organisms will accumulate to the detriment of future consignments.

The present invention is particularly concerned with the provisions of apparatus, for monitoring changes in a physical quantity with time, which includes a reader unit and at least one sensor unit containing electronic components arranged to measure the physical quantity at predetermined time intervals and to store measurement data with corresponding time data, the or each sensor unit also containing communication means for transferring the measurement data and the time data from the sensor unit to the reader unit.

It is an object of the invention to minimise the bulk and cost of the sensor unit, and to avoid traps for foodstuffs, dirt, micro-organisms and the like.

According to one aspect of the invention such apparatus is provided with a sensor unit containing inductive coupling means adapted to receive energy from the reader unit to power the communication means.

Preferably the communication means is arranged to transmit data to the reader unit by receiving r.f. power from the reader unit and by varying the load which the sensor unit represents for the reader in accordance with the data to be transmitted.

The electronic components in each sensor unit may comprise measuring means for measuring the physical quantity, timing means for controlling operation of the measurement means to obtain measurements at predetermined intervals and for providing time data relating to each of the measurements, and storage means for storing the measurement data and associated time data.

The physical quantity will typically be temperature, the measuring means being, for example, a thermocouple, but other physical quantities may also be monitored with apparatus in accordance with the invention. For example, sound intensity may be monitored by incorporation of a suitable transducer in the sensor unit, permitting monitoring of noise levels in public places or within factories to determine whether regulations are being observed. Each sensor unit preferably contains a small battery for providing power for its electronics components other than the communications means.

In certain applications, for example for monitoring temperature in a cold storage room, it may be desirable to guard against removal of the sensor unit to another location (for example to a refrigerator) in order fraudulently to mask failure of the cold storage room by maintaining a temperature at or below the legally-required maximum. Accordingly, for such applications, the apparatus may comprise at least one base

unit co-operable with a sensor unit such that separation of the sensor unit from the base unit may be sensed or otherwise detected, the electronics components including storage means for storing the measurement data and associated time data, and the storage means also being arranged to store data regarding said separation. The detection means is preferably the inductive coupling means whereby the storage means will retain a history of the inductive coupling of the sensor unit with any reader unit. Alternatively, the electronic components in the sensor unit may be powered only by energy received from the base unit by the inductive coupling, whereby the sensor unit is only operative to store new data when inductively coupled with the base unit. The communications means is preferably arranged such that data may be communicated from the sensor unit to the reader unit irrespective of their relative orientation.

The present invention is also particularly concerned with a sensor unit, for monitoring changes in a physical quantity with time, comprising a body carrying electronic components arranged to measure said quantity at predetermined time intervals and to store measurement data with corresponding time data. According to another aspect of the invention such a sensor is provided with communications means in the form of an inductive coupling means, and the inductive coupling means is adapted to receive energy to power the communications means. Preferably the body is a plastics body enclosing the electronic components, the communications means and the inductive coupling means preferably by encapsulation. The inductive coupling means is preferably a coil encapsulated near the periphery of the plastics body. In this event the electronics components and the communications means may be positioned within the coils. Using technology currently employed in the manufacture of integrated circuit cards or "smart cards", the unit may be made relatively small, for example having, in plan, a shape and size similar to the ISO standard bank or credit card, with a thickness less than 10 mm, preferably less than 6 mm, for example 5 mm. Such a size and configuration would permit the unit to be inserted in packaged food to monitor temperature without significantly reducing space available for the food, the tiny power requirements of the internal electronic measuring and recording functions being provided by a very small internal battery which can be rechargeable through the inductive coupling.

By powering data transfer to the reader unit with inductively-coupled power from the reader unit, the internal battery in the sensor unit operating the other electronic components may be kept small, thus permitting the size of the sensor unit to be reduced. Encapsulation of integrated circuit components within a plastics body permits the sensor unit to operate in environments which would be deleterious to electronic components, and ensures a low thermal mass which, in the case of temperature monitoring, results in a rapid response to temperature change without the need for external temperature probes. The reduction in size to, for example, a thick credit card size, also reduces thermal mass, and reduces the volume occupied by the sensor unit, thus enabling it to be located where monitoring is required, without the need for external probes and the like. For example, sensor units in accordance with the invention may be packed with foodstuffs to monitor temperature not only of complete vehicle loads, but also of individual pallet loads forming part of the vehicle load, and even of high value packages forming part of pallet loads. The cost of the sensor units may be substantially less than known temperature monitoring devices, thus permitting their use for monitoring every load rather than sampled loads. The reduced size also simplifies coupling with a reader unit, precise alignment with the reader unit being unimportant, rendering the extraction of data via the reader unit to, say, a computer much easier. Typically, the sensor unit will be "initialised" by the reader unit, upon entry of a security code, for example, to clear existing data and to commence the data recording operation. Each reader unit may record in the sensor unit its own individual "signature" code for monitoring purposes.

Energisation of data may be carried out by the electronic components in the sensor unit, for security purposes and/or to compress the data to reduce storage requirements or increase the amount of data which can be stored. In one data compression technique, only significant changes in, say, temperature are recorded, so that repeated readings of the same temperature are not stored. The change necessary to trigger storage of new data may be varied. The data recording frequency may be varied according to circumstances. For example, different food types may require different temperature recording frequencies.

The invention will now be described by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is a perspective view of apparatus according to one embodiment of the invention, and

Figure 2 is a block diagram of the sensor unit forming part of the apparatus shown in Figure 1.

The apparatus shown in Figure 1 consists of a reader unit 1 upon which rests a self-contained sensor unit 2. In the position shown, the reader unit and sensor unit communicate with each other by inductive coupling, for example in the manner described in our UK Patent No. 2173623, which can be designed to function irrespective of the relative orientation between the sensor unit and the reader unit. A cable 3 connects the reader unit 1 to a personal computer and to a power supply, so that power is available for operation of the reader unit 1, and the data received from the sensor unit 2 can be passed to the personal com-

puter for further processing and, if desired, printed output. In use, the sensor unit 2 is first initialised by the reader unit 1 to delete existing stored data, to correct the internal clock, to calibrate the temperature measuring elements therein by reference to an accurate measuring device in the reader unit (after a suitable delay for temperature equalisation) and to start the new data recording sequence. The reader unit 1 may send to the sensor unit 2, for storage therein, data relating to the batch of goods with which the sensor unit is to be placed, and control data specifying the measurement intervals to be applied, according to the nature of the goods, for example. A security code permanently stored within the sensor unit 2 may be compared with a code entered into the computer via its keyboard. If the codes do not match, the sensor unit 2 may be arranged to ignore further instructions and data sent thereto by the reader unit 1.

Referring now to Figure 2, the sensor unit comprises a body 10 in which are encapsulated a substrate 11 bearing a printed circuit which appropriately interconnects a central processor 20, a memory 21 in the form of an EEPROM, a battery 22 (for example a lithium cell), a clock circuit 23, and two thermocouple devices 24 and 25. The components 20 and 23, for example, may form a single integrated circuit. A communications circuit 26 is also encapsulated in the body 10 and is connected to the central processor 20 and by connectors 27 and 28, on one side of the substrate 11, to an inductive coupling means defined by an inductive coil 29 extending around the periphery of the substrate on the opposite side from the connectors 27 and 28. The coil 29 thus provides inductive communication between the communication circuit 26 and the reader unit 1, thereby achieving a contactless interface. The two thermocouple devices 24 and 25 are spaced apart in the sensor unit to compensate errors due to local variations in temperature. Time data (including the date) is stored with corresponding temperature measurement data in the memory 21 at the desired predetermined intervals, after initialisation of the unit as hereinbefore described. When the sensor unit 2 and its associated load reaches the destination, the card is again placed on a reader unit and, after clearance of security codes as already described, the data from the memory 21 is transmitted via the communications circuit 26 to the reader unit 1.

The internal battery 22 can be very small as it only provides power to the central processor 20, the memory 21, the clock circuit 23 and the thermocouple devices 24 and 25. The duty cycle of the battery 22 is typically very low as the sensor unit is programmed to operate only for very short periods at relatively long intervals - for example, for 120 milliseconds every few minutes. When the sensor unit 2 is inductively coupled with the reader unit 1, the inductive field is arranged to over-ride the battery 22 so that the total energy demand for the sensor unit 2 will be derived from the inductive coupling which can also be used to recharge the battery 22.

The coil 29 would typically comprise about 15 turns and be formed as a printed circuit on the reverse face of the substrate 11. Preferably the coil 29 is tuned, for instance by use of a suitable capacitor, to a narrow range of frequencies to optimise the efficiency of the contactless interface.

For those applications where it is essential to keep a record of the times at which the sensor unit 2 is inductively coupled with a reader unit 1, this information may conveniently be stored in the memory 21 thereby generating a history of such inductive couplings.

For use with foodstuffs or livestock, for instance, the sensor unit 2 would be totally hermetically sealed. The body 10 would preferably be formed from a food grade plastic and would either be formed in two or more moulded pieces welded together (for instance by a peripheral ultrasonic weld), or be an encapsulation for all of the electronic components. Suitable food range plastics are the polyolefines and particularly high density polypropylene. One end of the body 10 may be extended to define an attachment, such as a hook or a hole for a fixing, whereby the sensor unit 2 may be positively secured to a pallet of foodstuffs or the like.

Each sensor unit 10 is unique and will require individual calibration. To this end the central processor 20 of each sensor unit may be programmed to perform a self-test of the sensor unit. In this manner groups of sensor units may be calibrated by subjecting them to a predetermined temperature and using a software instruction via the contactless interface to effect precise calibration. Similarly software instructions may be used to alter the programme sampling sequence of any sensor unit thereby adjusting the period of measurement and the timing of subsequent measurements to suit the user's requirements.

Claims

1. Apparatus, for monitoring changes in a physical quantity with time, including a reader unit and at least one sensor unit containing electronic components arranged to measure the physical quantity at predetermined time intervals and to store measurement data with corresponding time data, the sensor unit also containing communication means for transferring the measurement data and the time data from the sensor unit to the reader unit, characterised in that the sensor unit (2) also containing inductive coupling means (29) adapted to receive energy from the reader unit (1) to power the communication means (26).

2. Apparatus, as in Claim 1, characterised in that the

communication means (26) is arranged to transmit data to the reader unit (1) by receiving r.f. power from the reader unit and by varying the load which the sensor unit (2) represents for the reader unit (1) in accordance with the data to be transmitted.

3. Apparatus, as in Claim 1 or 2, characterised in that the electronic components include measuring means (24, 25) for measuring the physical quantity, timing means (23) for controlling operation of the measurement means (24, 25) to obtain measurements at predetermined intervals and for providing time data relating to each of the measurements, and storage means (21) for storing the measurement data and associated time data.

4. Apparatus, as in Claim 3, characterised in that the measuring means (24, 25) is arranged to measure temperature.

5. Apparatus, as in any preceding claim, characterised in that the sensor unit (2) additionally contains a battery (22) for providing power for the electronic components (20, 21, 23, 24 and 25).

6. Apparatus, as in any preceding claim, characterised in that the detection means (1,2) are arranged to sense separation of the sensor unit (2) from the base unit (1), the electronic components include storage means (21) for storing the measurement data and associated time data, and the storage means (21) is also arranged to store data regarding said separation.

7. Apparatus, as in Claim 6, characterised in that the detection means (1,2) is the inductive coupling means (29).

8. Apparatus, as in Claim 7, characterised in that the electronic components (20, 21, 23, 24 and 25) are powered by energy received by the inductive coupling means whereby the sensor unit (2) is only operative to store new data when inductively coupled with the base unit (1).

9. Apparatus, as in any preceding claim, characterised in that the sensor unit (2) comprises a plastics body (10) enclosing the electronic components (20, 21, 23, 24 and 25) and the communications means (26).

10. Apparatus, as in Claim 9, characterised in that the inductive coupling means (29) is also enclosed by the plastics body (10).

11. Apparatus, as in Claim 9 or 10, characterised in that the electronic components (20, 21, 23, 24 and 25), the communications means (26) and the inductive coupling means (29) are encapsulated by the plastics body (10).

12. Apparatus, as in any preceding claim, characterised in that the communications means (26) is arranged such that data may be communicated from the sensor unit (2) to the reader unit (1) irrespective of their relative orientation.

13. A sensor unit, for monitoring changes in a physical quantity with time, comprising a body carrying electronic components arranged to measure said quantity at predetermined time intervals and to store measurement data with corresponding time data, and communication means for transferring the measurement data and time data to a reader unit, characterised in that the communication means is an inductive coupling means (29), and the inductive coupling means (29) is adapted to receive energy to power the communication means (26).

14. A sensor unit, as in Claim 13, characterised in that the body is a plastics body (10) enclosing the electronic components (20, 21, 23, 24 and 25), the communication means (26) and the inductive coupling means (29).

15. A sensor unit, as in Claim 14, characterised in that the electronic components (20, 21, 23, 24 and 25), the communication means (26) and the inductive coupling means (29) are encapsulated by the plastics body (10).

16. A sensor unit, as in Claim 15, characterised in that the inductive coupling means (29) is a coil (29) encapsulated near the periphery of the plastics body (10).

17. A sensor unit, as in Claim 16, characterised in that the electronic components (20, 21, 23, 24 and 25) and the communications means (26) are positioned within the coil (29).

18. A sensor unit, as in any of Claims 13 to 17, characterised in that the body (10) has a thickness of less than 10 mm.

19. A sensor unit, as in Claim 18, characterised in that the body (10) has a thickness of less than 6 mm.

20. A sensor unit, as in any of Claims 13 to 19, characterised in that the body (10) is substantially the same shape and size as an ISO bank or credit card.

21. A sensor unit, as in any of Claims 13 to 20, char-

acterised in that the body (10) is formed from a food grade plastic.

22. A sensor unit, as in Claim 21, characterised in that the body (10) is formed from a polyolefine.

23. A sensor unit, as in Claim 22, characterised in that the body (10) is formed from a high density polypropylene.

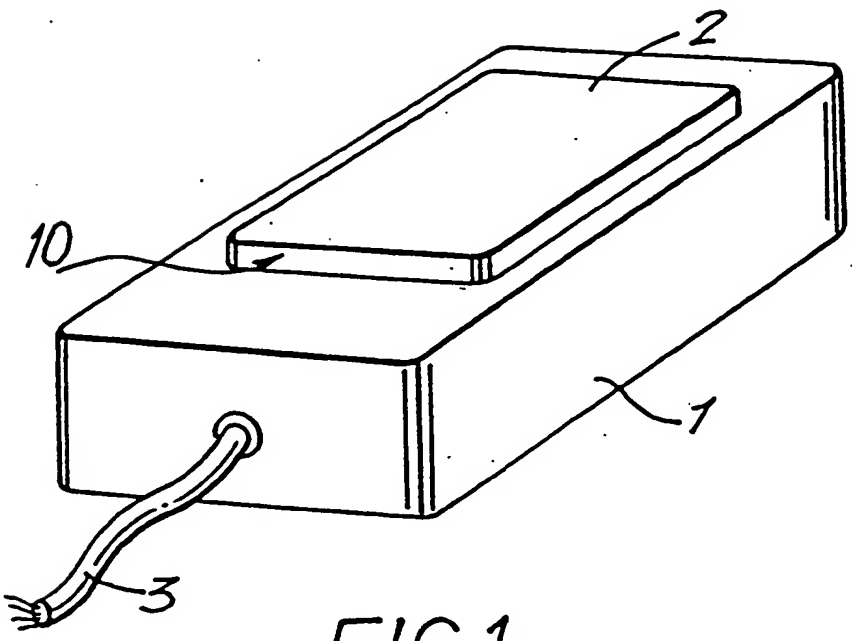

FIG.1.

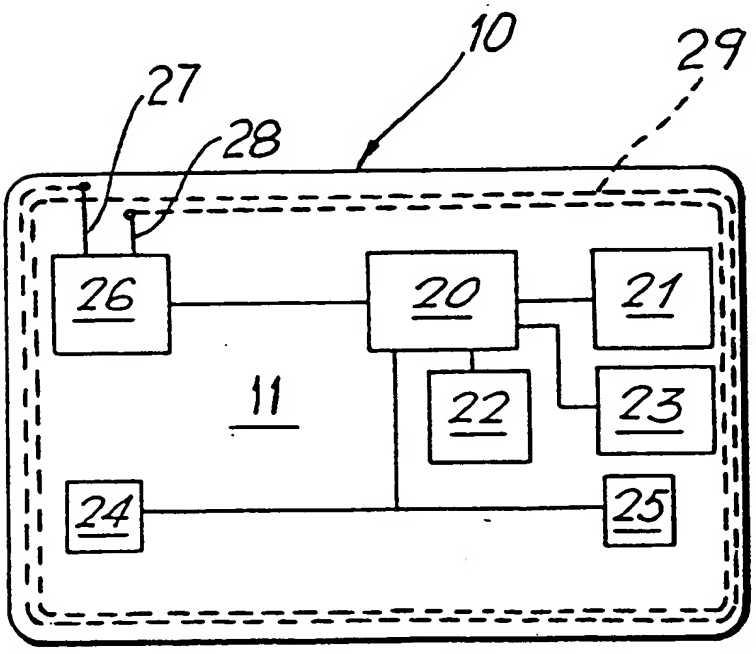

FIG.2.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number EP 92 30 3770

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
P,Y	WO-A-9 203 705 (ROSEMOUNT LTD) 5 March 1992 * page 2, line 2 - page 5, line 29 *	1,4	G01K1/02
D,Y	US-A-4 972 099 (DAI NIPPON PRINTING CO,LTD.)		
A	* the whole document *	1,4, 18-20 3,21	
D,Y	GB-A-2 173 623 (THE GENERAL ELECTRIC CO)		
A	* the whole document *	1,18-20 2,6-11	
A	NL-A-8 502 684 (GULLIMEX) * page 4, line 2 - page 4, line 5 * * page 5, line 15 - page 6, line 4 *	6	
A	WO-A-8 903 020 (SEKISUI JUSHI KABUSHIKI KAISHA) * abstract *	18-20	
A	US-A-4 781 378 (LUSTOUR CORP.) * the whole document *	21-23	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

G01K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 JULY 1992	RAMBOER P.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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